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ABSTRACT

A study described the social interactions of ability-grouped dyads as they construct knowledge of the scientific concept of balance to elucidate the relationship between interactions and conceptual growth. The verbal and nonverbal behaviors of 30 fifth-grade students were recorded as they completed three activities related to balance and levers. These student interactions were examined within a framework of social cognition. For each dyad, characteristics of ability-grouped dyads were identified. Results revealed that high students (those who scored in the upper quartile of the California Achievement Reading Test) effectively used prior experiences, maintained focus on the learning task, and were able to manipulate the equipment effectively to construct knowledge. Low students (those who scored in the lowest quartile on the California Achievement Reading Test) exhibited off-task behavior, lacked a metacognitive framework for organizing learning tasks, centered on irrelevant features of the equipment and were unable to use language effectively to mediate learning. Within low-high student dyads, high-achieving students modeled thinking processes and strategies for manipulating equipment and focused the low-achieving students on the components of the tasks while verbally monitoring their progress, thus enabling the low students to identify the critical features necessary for concept construction. These results highlight the differences that students manifest in the use of language and tools. Low students' inefficient use of tools has implications for the ways science teachers structure lessons and group students for laboratory work. (Contains 26 references.) (Author/RS)

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# Verbal and Non-Verbal Behavior of Ability-Grouped Dyads

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Abstract

In this study we describe the social interactions of ability-grouped dyads as they construct knowledge of balance concepts in order to elucidate the relationship between interactions and conceptual growth.

The verbal and nonverbal behaviors of 30 fifth-grade students were recorded as they completed three activities related to balance. These student interactions were examined within a framework of social cognition. For each dyad, characteristics of ability-grouped dyads were identified. Results revealed that high students (those who scored in the upper quartile of the California Achievement Reading Test) effectively use prior experiences, maintain focus on the learning task, and are able to manipulate the equipment effectively to construct knowledge. Low students (those who scored in the lowest quartile on the California Achievement Reading Test) exhibited off-task behavior, lacked a metacognitive framework for organizing the learning tasks, centered on irrelevant features of the equipment and were unable to use language effectively to mediate learning. Within low-high student dyads, high-achieving students typically modeled thinking processes and strategies for manipulating equipment. In addition, they focused the low-achieving student on the components of the tasks, while verbally monitoring their progress, thus enabling the low student to identify the critical features necessary for concept construction. These results highlighted the differences that students have in the use of language and tools. Low students' inefficient use of tools has implications for the ways science teachers structure lessons and group students for laboratory work.

## Verbal and Non-Verbal Behavior of Ability-Grouped Dyads

### Introduction

In this study we investigate the relationship between social interaction and the construction of knowledge about levers. Specifically, we are interested in the relationship between students' achievement levels, their interactions with peers and their knowledge construction. We recognize that factors such as social class and economic status have a strong predictive relationship to achievement. However, we investigate in a natural public school setting, the types of interactions that take place between students and how their interactions contribute to the joint construction of knowledge.

The roles that social interactions play in concept development are becoming increasingly recognized as integral to the learning process. Vygotsky explored the role of social interaction in learning and provided us with insight into the influence of social phenomena (Wertsch, 1985). Vygotsky's work indicates that mental development is embedded in the context of the sociocultural setting and learning behaviors emerge primarily from the collective rather than from the individual. It follows, therefore, that higher mental functions are social in origin.

> *From the very first days of the child's development, his activities acquire a meaning of their own in a system of social behavior and, being directed towards a definite purpose, are frequently refracted through the prism of the child's environment. The path from object to child and from child to object passes through another person. This complex human structure is the product of a developmental process deeply rooted in the links between*

*individual and social history*. (Vygotsky, 1978, p. 30)

Higher mental functions have been described as primarily interpsychological (group, dyad) processes. These functions originate between and among individuals. These functions move to an intrapsychological (individual) plane by a series of mechanizations determined by the individual's mental processes. That is, learning may be viewed as being first developed in small groups (ie. dyads), and are precursors to the intrapsychological, that is, individual processes (Wertsch, 1979).

On both the intra- and interpsychological plane, the development of higher mental functions is mediated by the use of tools and signs (Wertsch, 1991). Tools are those concrete objects that can be manipulated in the external environment, whereas signs are symbolic representations such as language or arithmetic. Important to the mediation process and to the collective and individuals ways of knowing are the tools and signs selected for use, and the manner in which they are used.

Vygotsky also described the zone of proximal development as a component of social cognition. He defined the zone of proximal development as the intellectual potential of an individual when provided with assistance from a knowledgeable adult or a more advanced child. During this assistance process, this individual is "other regulated" by a more capable peer or an adult. This "other regulation" refers to cues provided by the more capable peer or adult. The individual, by means of this assistance, is able to move through a series of steps that eventually lead to "self-regulation" and intellectual growth. Vygotsky stressed the importance of the zone of proximal development because it allows for the measurement of the intellectual potential of an individual rather than on what the individual has achieved. Researchers have become increasingly interested

in the relationship between the zone of proximal development and peer interactions in educational settings.

In recent years, the constructivist theory of cognition has been accepted by many as a viable framework for understanding how students construct knowledge about science and the world around them. Cognitive construction is based on a belief that individuals build or construct their own knowledge. This "theory of knowing" has at its roots social interaction (von Glasersfeld, 1992). According to constructivist theory, the individual's knowledge of the world is bound to personal experiences and is mediated through interaction (usually through language) with others (von Glasersfeld, 1989). Learning from a constructivist perspective has been characterized as the following:

> Knowledge is never acquired passively, because novelty cannot be handled except through assimilation to a cognitive structure the experiencing subject already has. Indeed, the subject does not perceive an experience as novel until it generates a perturbation relative to some expected result. Only at that point the experience may lead to an accommodation and thus to a novel conceptual structure that reestablishes a relative equilibrium. In this context, it is necessary to emphasize the most frequent source of perturbations for the developing cognitive subject is the interaction with others. (von Glasersfeld, 1989, p. 136.)

Several other researchers have investigated learning within a social cognition context. Studies of peer interaction-achievement relationships in a variety of contexts have indicated that students working together are more successful than students working individually (Ames & Murray, 1982; Dansereau, 1988; Larson, et. al, 1984; McDonald, 1985). Attempts to isolate the factors that contribute to the

cognitive growth of peer-peer tutoring dyads have suggested that verbalization is a critical component (Annis, 1983; Botvin & Murray, 1975). Slavin (1980, 1990) speculates that the elaboration and verbalization of material from intergroup tutoring that takes place during cooperative learning aids in the cognitive restructuring of information (Burron, James, & Ambrosio, 1993). Webb (1982) also reported that verbal interactions contributed to the highest achievement gains in group work. Webb reported negative achievement effects were associated with students to whom answers were given without the accompanying explanation.

In a previous study (Carter & Jones, in press), we examined the achievement of students paired by ability and found that high achieving students (those scoring in the upper quartile on the California Achievement Reading Test) whether paired with low achieving students (those scoring in the lowest quartile on the California Achievement Reading Test) or other high achieving students for a series of laboratory activities had equivalent gain scores on a lever concept test. Low achieving students paired with high achieving students scored significantly higher than those low achieving students who were paired with other low achievers. A quantitative examination of laboratory behaviors indicated that there were behavior differences for low achieving students by dyad type. Low achieving students paired with other low achieving students had significantly more instances of tinkering, more block movement, as well as more instances of distracting behavior.

High achieving students paired with low achieving students spoke significantly more words, took more turns speaking and exhibited significantly more helping behaviors than when paired with another high achieving student. There were no significant differences in tinkering (manipulation of the equipment not directly related to

answering the questions on the laboratory sheets), block movement or disturbing behaviors for high achieving students regardless of the ability level of their partner. The frequencies of these behaviors led us to inquire further into the nature and context of verbal and nonverbal behaviors of these ability-paired dyads. We were particularly interested in examining the interactions of the dyads with respect to how social interaction may influence cognitive development. Thus, we investigated the following research questions:

•What are the verbal and nonverbal characteristics of low and high achieving student dyads?

•How do interactions and behaviors of high-low student dyads differ from high-high and low-low dyads?

•How do students of different ability dyads construct knowledge of balance?

## Method

### Subjects

Three experienced fifth-grade teachers volunteered to participate in the study. Each teacher taught science in a large elementary school located in an urban area of North Carolina. Three classes from each teacher and school participated in this study.

Prior to beginning the study, California Achievement Test (CAT) scores for reading were obtained for each student in the nine participating classes. Each student was assigned to one of three quartile ability groups based on the reading score: high, average or low, paralleling the quartiles achieved by the school system. High-achieving students (those in the upper 25%) were paired with a low-achieving student (lowest 25%), or another high-achieving student. Low-achieving students

were paired with another low-achieving student or with a high-achieving student. Average-achieving (mid-range 50%) students were placed with other average-achieving students. A stratified random selection process was used to assign students to dyads based on CAT scores. We recognize that ability and achievement are not synonymous, but for the purposes of this study we use the California Achievement Test scores as a general indicator of students' ability to succeed in school.

Students were pre- and posttested individually using the Lever Concept test (Carter, 1991). This seventeen item instrument has a reliability coefficient of 0.73. Validity was previously established by an expert panel. The pre-post testing and two (55 minute) laboratory periods of lever activities took place over three weeks.

Prior to each lever activity, the principal investigators reviewed prerequisite concepts and skills using a standardized script. These preliminary concepts included the use of the spring scale to measure force, concepts of force and work, the use of levers in everyday life, and the identity of the fulcrum.

Student dyads worked together to complete lever activities that were designed to allow for joint exploration of concepts about the effect of moving the fulcrum on effort force needed and balancing levers using both equal and unequal weights. Students were instructed to discuss with their partners the lever activities as well as to read instructions to each other aloud as they worked through the two laboratory activities.

In the first set of activities, student dyads were asked to discuss and predict the amount of effort force needed at various locations on the lever to lift a stationary weight. Student dyads checked their predictions initially by using the spring scale. The goal of the second set of activities was for student dyads to construct balance concepts by completing activities that required them to predict and experiment with

balancing the lever using blocks of equal weight. Upon completion of each set of activities, student dyads were given application problems that required them to verbally express their understanding of balance concepts. As previously reported, low achieving students working with other low achieving students had no significant pre- to post-test gains (X= 0.8). Low achieving students working with high achieving students showed significant gains in achievement (X=2.6). High achieving student gains were equivalent regardless of their partner's ability level (High with High, X=2.6; High with Low, X= 2.6).

In order to capture the specific microenvironment of the dyad interactions that led to these results, a stratified subsample of 30 students was randomly selected for intensive case study. The subsample consisted of students from the following ability pair types: high-low, high-high and low-low students. Average students were not used in the case studies. Three observers trained in qualitative methodology were each randomly assigned to record the verbal and non-verbal behaviors of a single student dyad. The case study dyads were also audio recorded using a separate audiorecorder and clip-on microphone.

Laboratory materials

Each dyad was furnished with a wooden lever constructed for these activities. The lever was 20 inches long and 2.5 inches wide. A bolt through the center of the lever served as the point of attachment to the wooden stand. The lever was marked off and numbered from each side of the fulcrum bolt. Dyads were also provided with a spring scale, a square box containing a weight, and a set of blocks differing only in color.

**Analysis**

The audiotapes were transcribed and merged with the field notes to provide a record of the dyad interactions. The field notes and audiotapes were analyzed across and within different ability pairing of students as described by Erickson (1986). As the field notes and transcripts were analyzed, categories of behaviors were identified. As categories were created, responses were compared and contrasted across students (Miles & Huberman, 1984). Initial categories included these verbal and nonverbal behaviors: decision-making, correcting, explaining, off-task behavior, metacognitive behaviors, competition, motivation, checking for understanding, sharing equipment, offering advise, praise, not paying attention, and following directions. Student ability type behaviors were examined and reexamined for evidence of representative characteristics. Categories were modified and redefined as characteristics of ability types emerged. Multiple readings were made independently by three or more researchers as categories of behaviors were identified, discussed and verified.

The analysis was conducted under a framework of social cognition. Transcripts and fieldnotes were carefully analyzed to examine evidence of conceptual development related to balance. Particular attention was paid to the differences in the interactions and behaviors of the ability-paired dyads. For each dyad type, we identified the sequences of interactions and behaviors that represented the characteristics typical of that dyad. These interactions and behaviors became the basis for a narrative describing the dyad types followed by a summarizing dyad profile. The narratives we have constructed possess a specific syntactic shape including a beginning-middle-end, as well as for some dyads, a situation-transformation-situation (Scholes, 1981). For each narrative, we describe the typical behaviors of a dyad that represents a common

composite of the students we studied of that dyad type. The narrative is supported by exact quotes extracted from the audiotapes. Pseudonyms have been used in place of student names. The narratives attempt to capture the complexity, specificity, and interconnectedness of the dyad relationships (Carter, 1993). We recognize that these narratives are not completely objective but are bounded by the researchers' perspectives, the research questions, as well as our ability to interpret the words and actions of our research subjects. However, it is the richness of the context, along with the objective, discrete units of data, that provide us with an understanding of how the relationship between two high achieving students differs from a high achieving student paired with a low achieving student. The narratives we construct "are a means for interpreting and reinterpreting events by constructing a causal pattern which integrates that which is known about an event as well as that which is conjectural but relevant to an interpretation" (Robinson & Hawpe, 1986, p. 112).

## Results

### Low - Low Dyad

Lisa is a white female with a California Achievement reading test score in the 24th percentile. Lisa's partner, Linda is another low achieving white female student. Lisa and Linda enter the room, sit down and immediately focus on the lever that has been placed on the table. Lisa and Linda immediately grab for the lever and each girl tries to pull it closer.

As the teacher begins to give the directions, Lisa's attention appears to wander. She plays with the equipment, bites her fingernails, flexes a bracelet, and toys with a magazine tucked inside her desk. When the teacher asked students to write the name

of their partner on their laboratory sheet, Lisa asks her partner how to spell the word *partner*. Upon being told to begin work, Lisa expresses uncertainty about what she is expected to do. The written activity sheet eventually draws her attention to the first task. Initially, Lisa appears interested in the equipment and comments that this laboratory activity ought to be fun.

*Lisa: This is better than (science) class.*

*Linda: This is math. It is kind of like math.*

*Lisa: You can do it (the lever activities) like that.*

As Lisa works through a few problems, the novelty of the activities appears to wear off and her enthusiasm wanes. Lisa states that she is confused about what is to be done with the equipment and how the teacher wants the worksheet filled out. Once she figures out the directions, she focuses on the task of filling in all the blanks on the worksheet.

The two low achieving students do not discuss the patterns emerging from their actions balancing the blocks. Lisa tends to have a narrow focus, looking at one aspect of the task at a time. She is primarily concerned about getting the worksheet done. At one point Lisa enters her answer in the wrong place. She argues with her partner about which number they were on. She realizes she has marked the wrong answer on her paper and she is very concerned. Lisa spends quite a bit of time and effort worrying about how to fix her answer.

*Lisa asks: How do we draw that?* [She then expresses concern with the way the drawings look.]

*Lisa: I had to scratch through my paper when I messed up. It don't look right. I messed up my pages.* [Field notes indicate that Lisa is unable to

continue work immediately due to her concern about her paper.]

Finally Lisa returns to the task and the two girls complete the activity. They have not discussed patterns or given any indication that there may be more to the task than finishing the worksheet.

The girls begin the second set of activities by arguing over who gets to hold the equipment. They settle this argument by dividing up the equipment into two piles whenever they can. Lisa makes sure that she gets her fair share. Linda grabs the bag of blocks and Lisa says:

*Lisa: I want to get all the red ones.*

*Linda: You get what I give you.*

*Lisa: Four yellow ones.*

*Linda: You get what I give you.*

*Lisa: You don't have to be so mean.*

*Linda: We got an extra block.*

*Lisa: We got an extra block.*

*Linda: OK we will just put this extra one right here.* [Linda puts it on the center of the lever.]

Both girls continue to focus on the equipment throughout the learning sessions. They focus on the color of the blocks and how the lever is made, rather than what is the result of their explorations. In the middle of an activity designed to lead students to an awareness of an emerging pattern, Lisa comments: *"Lets use different colors."* They work through each problem of the activity, although field notes indicate that they often record answers in the wrong place, negating the usefulness of their answers. They appear confused about where they are in the activity. Once again losing

concentration, Lisa plays with the lever, picks it up and dangles it by the fulcrum.

*Lisa:* [turning to two nearby girls ] *Do you like this?* [They respond: *Yeh, it is fun.*]

*Lisa:* [Taking two pens out of her desk ] *I wonder which of these weighs the most?* [She takes out pens and puts them on the lever. Lisa and Linda then move the pens to the far ends of the lever. They take out pencils and put them on the lever.]

*Lisa: That's probably heavier* [indicating her pencil] *because it has an eraser on it* [The teacher comes by and the two students quickly grab their pens and pencils, hastily removing them.]

Returning to the task, Lisa ventures a prediction about block placement, as she has been instructed to do. Her partner is not supportive and usually disagrees although it is evident that she has very little understanding of the nature of the activity, and appears to have no idea of whether or not Lisa's prediction is right or wrong. When Lisa tries out her prediction, her partner makes fun of her when she is wrong.

*Linda: We got that wrong because you just balanced it on "1" and it's supposed to be balanced on "2".*

*Lisa: It's going to be the same way.*

*Linda: No, it won't.*

*Lisa: You think you know everything.*

*Linda: I know.*

*Lisa: You don't.*

*Linda: Cause see, watch. Ha ha, yours won't balance.*

*Lisa: Yeah, I know why yours balanced, because you copied.*

*Linda: It is three. Told you.* [This was said smugly as she began to sing.]

*Hahahahahahaha.*

Lisa offers excuses as to why she may have predicted incorrectly. Midway through the activities, Lisa gets an idea that she wants to try but her partner maintains control of her side of the lever and refused to let Lisa experiment. (Each girl has agreed to have ownership of half the lever.) As time goes on, the blocks and the equipment are spilled with increasing frequency. As the teacher nears Lisa's desk, she gives a status report to the teacher, including an accusation about the quality of Linda's work.

*Lisa:* [ Reports to the teacher] *I tried to keep it balanced. Mine didn't balance but hers balanced because she copied this.*

*Linda: No I didn't!*

The third activity progresses much like the second. Whenever Lisa ventures to give directions or explanations she is typically ridiculed by her partner. The two low achieving students frequently get into a game of one-up-manship. When Lisa does not know an answer she asks the teacher for assistance and generally does not trust the answer given to her by her partner. There are random off-task verbalizations throughout the second and third activities. These verbalizations between the two girls are essentially monologues, with both people talking, but with little actual conversation going on. The following verbatim transcript illustrates this point.

*Lisa: I can take my recorder and play it with my nose.*

*Linda: I would have killed my sister...[goes on about her family life.]*

*Lisa: Our TV has cable.*

*Linda: We need to get our air conditioner fixed.*

*Lisa: I'll measure my arm now [She uses lever to measure.] Big feet run in*

*our family.*

*Linda: My bangs go like this.*

*Lisa: If you cut your eyebrows with a razor it would look real funny.*

*Lisa : This stuff isn't any fun anymore.*

*Linda: Are we done?*

After completing the worksheet, Lisa continues playing with the equipment but there is a destructive side to the play.

*Lisa: OK... Let's see the back of this thing (the lever). It is green and black.*

*Linda: Can I see?*

*Lisa: See, it is green and black.*

[She grabs the lever and plays with it like a seesaw. Linda is humming, and takes a United States flag out of her desk and waves it. Lisa initiates a contest with her partner while playing to see whose blocks stay on the lever as it is shaken.]

*Lisa: I had a yellow, a green and two oranges.*

*Linda: I had 2 oranges, a green, a red, and an orange.*

*Lisa: No fair. Let me shake and see if they fall.*

*Linda: Come on yellow, stay there.*

The girls begin cheering for different colors to stay on the lever as they shake the lever. As the teacher calls an end to the activity, the girls put up their equipment and leave the classroom.

Low-Low Dyad Summary Profile

The low achieving student was typically inattentive when important introductory

material and directions were being given. As a consequence, the low achieving student entered the learning experience with almost no framework for organizing the steps of the immediate task and for understanding the ultimate purpose of the activities. Without this framework, the low achieving student's focus was random and fleeting as she grasped for a task that was within her range of experience (ie. filling in the worksheet.) The interest of the low achieving student in completing the worksheet in a neat and complete manner suggests that perhaps the student has been rewarded in the past for such behavior. When the opportunity for cognitive success was not available, this student reverted to her schema for partial success.

Lack of structure for the learning situation consistently led to off task behavior and frequent refocusing. This refocusing appeared to be random as the low achieving student looked for structure. We hypothesize that this lack of structure can lead to feelings of discomfort. This discomfort was externalized as frustration, hostile, isolated behavior and ultimately dislike of the task that had initially appeared interesting.

There is evidence of centration as the low achieving student focused first on one area of the task, then another. There is no evidence that the low student was able to approach the task as a whole. One roadblock to decentration was the material ownership strategies used by low students. Whether due to socioeconomic or lack of prior experience, low students competed for use of lab materials to such an extent that they negated the beneficial use of these tools for constructing concepts.

High - High Dyad

Jane is a white female who has high test scores on the California Achievement test

in the 93rd percentile. Jane is sitting quietly and listening as the teacher introduces the lever activities. She raises her hand when the teacher asks for volunteers to describe what is meant by the term "work". After the teacher completes the introductory material, Jane and her partner, Jill (another high-achieving, white student), quickly begin their work on the activity. They take out the lever, weight and spring scale and set up the equipment. Jane begins to examine the components of the homemade lever and accurately identifies the screw [actually a bolt] as the fulcrum of their lever. She and her partner try to use their prior experiences and the introductory information to place the upcoming activity into a contextual framework.

*Jane: What do you call the things that are on here?*

*Jill: These? Little blocks.*

*Jane: I know. But you have a name like a fulcrum. That is like a screwdriver, Jill.*

*Jill: OK , but that's the screw. It is also called the fulcrum.*

Both girls are observant about the materials that are to be used. Jane continues to be curious about how the lever is constructed. She mentions this to her partner but neither Jane nor her partner allow this curiosity to block their progress. They examine each piece of equipment but focus on how to use the equipment to get the exercise done. Jane is not overly concerned about what her partner is doing; she seems to know that her partner is a capable person. She appears relaxed about the task ahead of her. There is no competitiveness over the equipment. Jane asserts her right to have half of the turns in manipulating the equipment, but the cooperation is congenial.

*Jill:* [Uses the spring scale to measure the amount of force needed to lift the

object.] *80.*

*Jane: I want to do another though because I didn't have to do anything.*

*Jane: Whose desk do you want it* [the lever] *to be on?*

*Jill: It doesn't matter.*

The two high achieving students have frequent initial discussions about the tasks. Jane appears interested in searching for patterns immediately and often relates the pattern to everyday experiences.

*Jane: Look at the answers. First 200 grams, 160 grams, 120 grams, 80 grams, 0 grams, 250 grams, more than 250 grams.*

*Jill: yep.*

*Jane: Do you think that the higher up* [further from the fulcrum] *you put it the more weight it is? ...So that means everything the further it goes up* [closer to the fulcrum] *the less ...it has, right?*

*Jill: Right!*

*Jane: It is easier because the closer you move it the less weight... It's like a seesaw. You know the closer you get...*

Because her partner seems to understand what is going on, Jane doesn't explain it extensively or even finish her thoughts aloud. However, occasionally she checks to see that her partner understands what she understands. She is confident that she is doing the work correctly because she has followed directions and has confidence in her ability to understand.

*Jane: Did we do it right? I think so, we followed the directions.*

Throughout the activities the girls express their pleasure in the task and the equipment they are using.

*Jane: I like the spring scale, it's cool ...This is going to be fun ...So I like this it's fun...This is fun, this is great.*

Jane's comment although incorrect, reveals that she is attempting to draw from her prior experiences while answering the question. Her answer indicates that she understands how people of unequal weights can balance each other on a seesaw. The girls complete the first set of activities and begin to talk about the first summary question. A picture of a mother and her child at a park is shown and students are asked to explain to their partner where the mother should push on the seesaw and where her child should sit to make lifting the child easiest. Although Jane answers the first question, together they illustrate the correctness of the answer by using the lever cooperatively.

*Jane: You put the mother on the "1"* [ the lower the number on the lever the closer its position is to the fulcrum.] *and the child on the "5", on the other side.*

The girls listen attentively to instructions for the second set of activities without fidgeting or playing with the equipment. As they begin the first task, Jane immediately keys in on the important block variable, and wonders aloud if the blocks all have the same weight.

*Jane: Do the same colors* [of blocks] *have the same weight?*

*Jill: I don't think that the colors matter. Let's ask the teacher.*

After the teacher assures them that the blocks all have the same weight, their interest in the color of the blocks ends. They briefly discuss the task and begin working to solve the problems. Jane looks at the task and realizes that pattern finding is important to the successful completion of the task. The pattern for balancing becomes

readily apparent to her and she begins to operate on the basis of this pattern. Jane reminds her partner that they need more proof before they accept a pattern. She is not embarrassed or threatened by the idea that her idea might be wrong.

*Jane: 4 and 2. Lets try 3 and 1. No how about 5 and...*

*Jill : 5 and 3. Or 5 and 2.*

*Jane: No hold on. 5 and 1. Think of what 4 and 2 equals. 4 and 2 equals 6. You know how I got that?*

*Jill: How? I think I know how.*

*Jane: ..that could be the pattern... it might not always work, we don't know yet.*

It quickly becomes obvious as they continue to work that the partner sees the pattern too. The amount of verbalizing begins to decrease rapidly after the girls realize that the pattern is holding true. The third set of activities serves to reinforce their previous work; rapidly and almost silently they work to manipulate the blocks and record the answers on the sheet provided. Periodically, the two girls monitor their progress to make sure they are on the correct problem and are following the directions. They quickly complete the third set of activities. Jane is obviously pleased with the work they have completed.

*Jane: We are awesome!*

The girls remain interested in the lever and the balancing activities.

*Jane:* [To the teacher] *Can we try different ones after we've done all the ones on the sheet?*

The girls begin to examine the equipment more carefully now that they have some free time to manipulate the equipment. They notice that there are thumbtacks on the bottom

of the lever. They do not try to remove the tacks but they speculate on their possible use. To check the correctness of their suppositions they ask the teacher.

At the end of class, Jane returns the equipment to the correct place and turns in her written work to the teacher.

*Jane: Thanks, that was fun!*

High-High Summary Profile

The high achieving student entered the classroom and was able to immediately focus on the task at hand. It appeared that the high achieving student had the necessary prior experience and knew how to use teacher directions to begin constructing concepts without a waste of time. The high achieving student was efficient and organized, seldom getting off task. Although the high achieving student showed curiosity about the equipment, the high achieving student was able to delay satisfying her curiosity until the work was finished or she worked in such a way that her curiosity did not interfere with the task.

The high achieving student worked cooperatively with the other high partner. Although there was competition, it took place within a cooperative, task-oriented, framework. The competition did not appear to interfere with the learning process. Apparent in the high achieving student's interactions was an underlying assertiveness toward doing a share of the work. She seemed to realize the importance of using the equipment in constructing knowledge. The high achieving student was very articulate and verbalized both as a process of self-monitoring and as a way to seek validation from the partner.

Low - High Dyad

Hank is a high-achieving male with a California Achievement Test score in reading in the 98th percentile. His partner, Lester, is a low-achieving student with a California Achievement Test score in reading in the 22nd percentile. As the teacher is giving the instructions, Hank listens attentively while Lester fidgets with the microphone hanging around his neck and watches the researcher covertly. As they begin work, Hank asks Lester if he would like to hold the lever. Hank takes the lead in reading the directions aloud and structuring the activity.

*Hank: Ready? Do you want to hold it?*

*Lester: Yeah.*

*Hank: ... Now, let's wait a sec. Let's make sure that we're setting everything up right. Now, that [spring scale] goes on the"4" and the block goes on "5". Hank. I'll tell you when it's level. You just have to pull. You have to pull real hard. OK. -A little bit more, pull a little bit more. OK stop. You got it. Great.*

Lester complies with Hank's instructions wordlessly. Hank continues to read the problems aloud and shows Lester where to place the answers on the answer sheet. At Hank's insistence the two boys alternate using the spring scale.

*Hank: OK, 180.*

*Lester: 180?*

*Hank: It's 180. So on your worksheet put 180. OK, effort force equals 180 grams.*

Lester reads the spring scale incorrectly and Hank stops him and asks him to try it again. When Lester gives an answer without units, Hank insists that he complete the

answer by adding grams to his response. As they work through the activity, Hank thinks aloud about the pattern that is emerging from the data.

*Hank: What do we do? Just think of the answers in our minds, OK? When you move the block closer to the fulcrum what happens to the amount of force you need to lift the block? It..it when you move it closer to the thing* [fulcrum] *it's easier.*

Lester flips through all the pages of the activity sheets and moans aloud at the number of problems to be done. Hank ignores Lester's comments and continues to work through the activity. Hanks explains the summary questions at the end of the first activity.

*Hank: What you have to remember is how I did mine. On this one I said the rock.... the rock should be on 1 and the person should push down on 5 and that would be easier.*

*Lester: Yeah.*

*Hank: Well, that's what you've got to do.*

As they end the first lesson, Lester plays with the equipment. He places his watch on the spring scale and tries to balance his pencils on the lever.

As lesson 2 begins, the teacher instructs the students to get out the materials for the activity. They remove the blocks from their desks, and Lester immediately grabs all the purple ones to build a structure. Meanwhile, Hank reads the directions aloud. Hank tells Lester that the teacher has suggested that the blocks need to go on the middle of the line.

When it becomes necessary to use additional blocks in the activity, Hank politely suggests to Lester that he remove a purple block from the structure he has created on his desk and place it on the lever at the appropriate place. Although Hank has a

strategy for where to put the blocks, he asks Lester to predict where he thinks the blocks should go.

*Hank: First we have to predict. I think it will be 1 and 2. What do you think it will be? You have two blocks to use.*

Initially, the two boys use trial and error methods. After a few problems, Hank verbalizes his observations about the relationships of block placement to the balancing of the lever. On one problem Hank is the first to predict block placement, he then politely asks Lester for his prediction. Lester appears to acknowledge that Hank has a better grasp of what is going on.

*Hank: Do you agree* [with the prediction]?

*Lester : There's no way I couldn't agree. I'd be lying if I didn't.*

Lester begins to sing into the microphone and makes a comment about the neighboring students. Hank responds by pointing to the place on the activity sheet where Lester needs to record the next answer. Upon completion of the second activity, Lester is still unsure of the pattern and the meaning of the exercises with the lever. The boys begin work quickly on the third set of activities. Immediately Hank is able to correctly predict where the blocks should be placed.

*Lester: Your really good, Hank*

When it is Lester's turn, he incorrectly places the blocks, but he mimics Hank's observation that there are too many blocks on the side of the balance that touches the table. Lester then seems to seek reassurance from Hank that the activity is going well. "This is fun isn't it, Hank" The complete pattern emerges for Hank. He verbalizes the relationship of blocks, distance from fulcrum and the balancing of the lever. Hank comments that the lever works like a see-saw.

During Lester's next turn, Lester is not able to predict where the blocks will go using the pattern that Hank verbalized. Hank patiently shows him, using the lever, how to place the block so that the lever will balance. Lester is still not certain of the relationship between the block placement and balancing. The boys continue to work through the problems with Hank correctly predicting and encouraging Lester to take his turn placing the blocks. Hank is pleased that the pattern is working for each trial. He happily explains the relationship once again. Lester begins to see the pattern. He accurately predicts a block placement. As he continues to accurately predict block placement, his confidence seems to grow.

*Lester:* [Predicts] *This is 3. Two and one.* [The lever balances]

*Hank: Gosh, Lester, you're getting good at this.*

By the completion of the third activity Lester is able to see the pattern and meaning of the activity. This is illustrated by his correct answer to the summary application question. His pleasure at understanding is visible on his face and in his final words.

*Lester: I understand. Oh my god. We are bad.*

*Hank: Yes we are.*

High-Low Profile

The characteristics that high-low dyads together brought to the task were not different from their peers in homogeneous dyads. The high achieving students brought to the lessons attentiveness, on task behaviors, prior experiences, and an understanding of the strategies necessary for learning. The low achieving students had trouble paying attention, did not understand the task, focused on irrelevant details, and had trouble with self-regulation. However, as the high and low achieving students

interacted, differences in their metacognitive behaviors emerged. The intensity of focus of the high achieving student seemed to draw the low student's attention to the learning task. The high student kept the low achieving student on task by verbal encouragement and by nonverbal sharing of the equipment. The high achieving student's cooperative behaviors facilitated the low student's attention to the task at hand. In some cases, the high achieving student modeled thinking processes aloud as well as strategies for the manipulation of equipment. The high achieving student slowed down the often random behaviors of the low student and refocused the low achieving student on the task. The high achieving student also attended to the task logistics such as where to put the answers, how to use the equipment properly as well as keeping track of the number of the activity that they were working on.

## Discussion

The high achieving student brings to the activity a better developed scheme for learning. They have more prior experiences (or can more easily access their prior experiences) with see-saws, levers, screwdrivers and fulcrums. The high achieving student also has had more successful prior experiences with the completion of tasks. If the process is considered within a building metaphor, the high students have access to, and are able to read, the blueprint for construction. They know what tools they will need to accomplish the building task and they have the expertise to use these tools in an appropriate manner. Their prior experiences provides them with the foundation for their structure and their successful completion of other constructions supplies them with the confidence in their actions. They have a metacognitive framework to guide the inquiry.

The low students have been provided with the blueprint (the guided lessons) by the teacher. However, they can't read the blueprint and they are unsure of the tools they need for the construction. This lack of understanding of how to read the blueprints may reflect low students' failure to recognize that the separate elements compose a whole structure or may reflect lack of practice in building. In addition, the low student centrates on the details of the tools, rather than on how to use the tools. This inability to use the tools efficiently may contribute to the off-task behavior. Some of the low students are unable to focus on the building task because of other, more personal concerns, that they bring with them. When low students attempt to join the building process they begin building on one part of the structure, without the proper foundation, without understanding how the various parts are linked, and without a view of the final product. Students inexperience with the available tools leads them to begin and quit projects without completing one and before beginning another one. These low students, when working with other low students, are not able to access help with their constructions because neither student has the experience with tools and language to mediate the process.

When the high and low students work together, they each build successful, but parallel structures. The structures may not be identical, but each achieves the goal of the builder. The high student assists the low student with reading the blueprint and with proper use of tools. The high student also constantly looks ahead and discusses prior experiences. As a consequence, the low student may be able to develop a metacognitive framework. Although the low student may not hold a picture of the final product, the low student accepts that the high student has a vision of the work. The low student is encouraged by the high student to continue the building process, even when

discouraged or when she has lost her place. The high student encourages the low student to verbalize, thus using the signs that Vygotsky identified as mediating higher learning. The high student models learning behaviors, as well as teaches, the low student. The low student does not necessarily mimic the high student, but he uses his own tools and materials in the building process. In the end, the two (knowledge) structures may look different (they each may have taken different skills and used different materials), but they are personally useful to the individual builder. The high achieving student who worked with a low achieving student, may build a similar, but different, structure from the high student who worked with another high student. These two structures appear to be functionally equivalent, but not identical. The signs and tools were used differently by the high-low dyads when contrasted with the high-high dyads. Other researchers have suggested that the process of verbalizing is an extension of the cognitive process and may force the individual to "think" more about the tasks they are completing (Ericsson & Simon, 1980). Further research on the construction and organization of knowledge by dyads of similar and unequal ability could provide insight into differences in knowledge construction.

## Implications

Some critics of student learning groups have expressed concern about the potential for exploitation of higher-ability students in heterogeneous groupings (Robinson, 1990). Advocates of gifted education have questioned whether students of very high ability are able to work at the rate and level of achievement that will challenge them if they are assigned to work with low achieving students (Mills & Durden, 1992). The results of this research show that high ability students provide focus and verbal

encouragement for low achieving students. We speculate that it is possible that the verbalization that took place may have strengthened the high ability students' conceptual understanding. The behaviors that we examined in this study, accompanied by the lack of any difference in achievement gains reported by Carter & Jones (in press), suggest that higher achieving students were not disadvantaged or exploited by working with students of low achievement. Coupled with the significant achievement gains made by low achieving students, this study provides strong support for the use of heterogeneous science laboratory dyads.

For the practitioner there are several additional insights into student interactions that can be drawn from this study. To a casual observer in the classroom it would have appeared that the students were consistently on task. However, the field notes and transcripts revealed that low-achieving students had trouble maintaining a focus and were often drawn into off task behavior. These behaviors were covert and would probably not be noticed by a casual observer in an ordinary classroom situation.

There were also different types of on-task behavior for the different ability-grouped dyads. High achieving students working on task were involved in looking for patterns and formulating generalizations, whereas, the low achieving student dyads worked to fill in the worksheets neatly. It appeared as if the low students were going through the motions of the learning task without engaging in the process. This is not to say that they were uninterested or unmotivated. Students appeared to be interested in the equipment and motivated to do the task. The results suggest that simply providing students with interesting activities and the accompanying equipment is not enough for conceptual growth. These low-low dyads were involved in "hands-on science" without "minds-on science".

The dyad interactions highlighted the differences that these students of varying abilities have in the use of signs and tools. The low achieving students inefficient use of tools has implications for the ways teachers group students for science instruction. The low achieving students lack of experience, as well as their almost irrelevant focus on the features of the tools, indicates the need for multiple opportunities to use tools in a variety of contexts. Instead of recipe formatted laboratories that prescribe when and how to use individual tools, these low achieving students need the opportunity to select and creatively experience how these tools can be used to build conceptual understanding.

Not only were low achieving students deficit in the use of tools, but they were also weak in the use of signs. This is not surprising because students were assigned to dyads based on their CAT reading scores. Low achieving students entered the learning task deficit in language, one of the signs that Vygotsky advocates as mediating higher thinking. Although the activities were designed to minimize reading level, it was apparent that the lack of verbal skills inhibited low achieving students' knowledge construction.

The results of this study should be interpreted in light of the fact the lever activities were challenging and multileveled. It may not be advantageous to merely place high and low students together if the task is not designed for growth at different levels.

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